Variable Descriptions of the A-train Integrated CALIPSO, CloudSat, CERES, and MODIS merged product (CCCM {C3M})

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Version: RelA2.v2
Last updated: October 2, 2009

C3M Variable Descriptions

The CALIPSO, CERES, CloudSat and MODIS, C3M, product combines data taken with different spatial resolutions from the various sources. Three 333 m resolution CALIPSO profiles and one CloudSat profile (1.4 km resolution) are collocated with each 1 km MODIS imager pixel using geolocation information from these instruments. When mean and standard deviation over a CERES footprint is needed, the CERES point spread function, PSF, is used to convolve the higher resolution data into the CERES 20 km optical footprint. The Point Spread Function (PSF) 95 percent energy cutoff centroid is 32 km. Other variables are reported from the original data product. Only the CERES footprint from each scan with the CALIPSO and CloudSat data closest to the CERES center is retained for this product.

The CERES Single Scanner Footprint (SSF) proposed Edition3 and Clouds and Radiative Swath (CRS) Edition2 file formats are included as a starting point for this data product. However, full MODIS coverage is used without the sub-sampling that occurs in the standard Edition2 CERES processing. These are referred to as full footprint. A second set of PSF-weighted cloud properties and radiances is obtained by using only the MODIS pixels that have been matched to the CALIPSO and CloudSat data. These are referred to as track footprints (or pixels over the CALIPSO CloudSat ground track). The CALIPSO and CloudSat data is used to improve the cloud properties derived from the MODIS imager (hereinafter, enhanced cloud algorithm or MODIS enhanced). The footprint using the improved information is referred to as "enhance track" and "enhance full". For the first generation product, only initially clear MODIS pixels that had matching cloudy CALIPSO or CloudSat profiles were modified.

The cloud or radiance variable within a CERES footprint has a distribution. For column integrated or one-dimensional variables, the PSF-weighted mean and standard deviation over the CERES footprint are kept. To maintain original cloud overlap information from the higher resolution profile data within a CERES footprint, we adopt a cloud grouping process in which profiles with similar cloud top and base height are grouped together. The cloud top and base heights and percent coverage of each group over the CERES footprint are reported.

For the C3M product, the variables that are part of the Edition3 SSF and CRS retain the variable reference number (or item number) from that product in the data product catalog even though they may have additional dimensions in the C3M. Those variables that do not have a SSF or CRS counter part were labeled with a CCCM variable reference number. The variable description for many of the SSF variables can be obtained from the SSF collection guide at http://science.larc.nasa.gov/ceres/collect_guide/ SSF_CG.pdf.

CERES-derived TOA irradiance

CERES SW TOA flux – upwards: Shortwave (SSF-38): TOA upward flux derived from CERES SW radiance by angular distribution models. The scene I.D. is based on MODIS-derived cloud properties over the entire CERES footprint with the preliminary Edition3 CERES-MODIS cloud algorithm.

CERES SW TOA flux – downwards (SSF-38a): Shortwave TOA downward flux computed with the solar zenith angle at the surface for the location and time of the CERES radiance observation.

CERES LW TOA flux – upwards (SSF-39): Longwave TOA upward flux derived from CERES LW radiance by angular distribution models.

CERES WN TOA flux – upwards (SSF-40): Window TOA upward flux derived from CERES WN radiance by angular distribution models.

Cloud and aerosol mask (CALIPSO and CloudSat)

In order to keep the information of CALIPSO and CloudSat derived properties at the original resolution as much as possible, we keep all cloud profiles when the number of unique profiles does not exceed our limit. After reviewing statistics of the number of unique cloud groups within a footprint and cloud layers in the profile, the maximum number of groups within a CERES footprint is 16 and the maximum number of layers within a group is 6. For the few cases where the number of unique group exceeded sixteen, a process was adopted to combine profiles with nearly the same cloud top and base height.

The CALIPSO and CloudSat cloud masks, obtained from the VFM and CLDCLASS products, respectively are independent and sometimes can differ significantly due to characteristics of the instrument used. This allows three combinations when the CALIPSO and CloudSat masks are paired: 1) CALIPSO is cloud-free in the column and CloudSat reports clouds, 2) CALIPSO reports clouds and CloudSat is cloud-free in the column, and 3) both CALIPSO and CloudSat report clouds somewhere in the column. If only one of the paired profiles is invalid, that profile is handle as if that profile was cloud-free in the cloud grouping process.

After identify three cloud mask combinations described above, cloud masks are compared at each vertical layers from each instrument. The vertical resolution of CALIPSO profile is 30 m below the altitude of 8 km and 60 m above the altitude of 8 km. The vertical resolution of CloudSat profile is 240 m throughout. Comparing cloud mask layer by layer, identical profiles are grouped. Where both CALIPSO and CloudSat profiles are cloudy, all profiles in which cloud boundaries are exactly mach are grouped together. If the number of resulting groups is less than 16, all groups are kept. If that number is exceeded, similar, less popular profile are combined together until the number becomes less than or equal to 16.

The process to reduce the number of cloud groups when it exceeds 16 is following. First, the number of unique profiles within a case, CALIPSO cloudy CloudSat cloud-free profiles, CALIPSO cloud-free CloudSat cloudy profiles, and CALIPSO and CloudSat cloudy profiles, is determined by

$$n_j^f = 16 \frac{N_j^i}{\sum_{i=1}^{3} N_i^i} \frac{16}{\sum_{i=1}^{3} n_i^i},$$

where *N* is the number of profiles in the case, n is the number of unique profiles in the case (i.e N>n) and superscript *i* and *f* indicate the initial and final. If the number of unique profiles in the case is within the limit of n_j^f, no combining is done for the case. If the limit is exceeded, all unique profiles that contain nine or more matches are kept. Then starting with the remaining profile with the most exact matches, other profiles that only differ by one are combined with it. If this fails to reduce the number of profiles below the limit, the last step is repeated combining profiles that differ by an increasing number of layers until the limit is met. The cases where the CALIPSO profiles were cloudy are handled in the same manner. The number of profiles from the CALIPSO cloud-free case is subtracted from 16 to find the limit used for the remaining cases. This will result in sixteen or less cloud groupings with the most frequent cases being retained without combination.

Mean altitude of surface above see level (CCCM-1): Mean surface altitude from CALIPSO VFM over a CERES footprint. Default value occurs when there is no good CALIPSO profiles in a CERES footprint or all CALIPSO signals are completely attenuated.

Standard deviation of altitude of surface above sea level (CCCM-2): Standard deviation of surface altitudes from CALIPSO VFM over a CERES footprint.

Surface spectral albedo (CCCM-3): Surface spectral clear-sky albedo at 7 wavelengths derived from MODIS narrowband measurements. 7 wavelength ranges are:
1: 620 - 670nm
2: 841 - 876nm
3: 459 - 479nm
4 : 545 - 565nm
5: 1230 - 1250nm
6: 1628 - 1652nm
7: 2105 - 2155nm

Non-default values only occurs when the albedo is available from the MODIS file OR a composite file created from a full season of MODIS file (for cases where lots of clouds occur). The clear sky spectral albedo is derived from a MODIS supplied look-up-table that is a function of solar zenith angle and aerosol optical thickness and that is derived by combining black(direct) and white(diffuse) albedos to simulate a clear sky albedo.

The total albedo(s) can also be obtained indirectly from the ratio of spectral up and down total sky surface fluxes (CCCM-105 and 106).

Modis spectral albedo ...Product Description
The 16-day 0.25 deg global BRDF/Albedo parameter product (MOD43C2) is a level-3 Climate Modeling Grid that provides the model parameters used to create the MODIS Global Albedo product (MOD43C1). The MOD43C2 product is offered on a flat latitude/longitude grid in HDF-EOS format. Three BRDF model parameter values are given for each of 10 wavelength bands (7 MODIS Land Bands, 459-2155 nm, in addition to 3 broad bands compiled from 300-700 nm, 700-5000 nm, and 300-5000 nm). These three weighting parameters (fiso , fvol , fgeo) are associated with the RossThickLiSparseReciprocal BRDF semi-empirical model which best describes the scattering (anisotropy) of each pixel. The data are stored band interleaved by pixel. Extensive quality information (in a bit-packed format) is also provided (720 rows by 1440 columns).

The global measures of albedo are derived averages that are computed from the 16-day 1-km global albedo product (MOD43B3). The 1-km global albedo is computed by integrating the Bi-directional Reflectance Distribution Function (BRDF), which describes the characteristic anisotropy of the land surface. The MODIS BRDF parameters (MOD43B1) are the best fit model weights determined by inverting the multi-date, multi-angular, cloud-free, atmospherically corrected surface reflectance observations acquired by MODIS over a 16-day period. These parameters can be used in a forward version of the model to fully reconstruct the surface BRDF and thus correct directional reflectances to a common view geometry or to compute the integrated black-sky (at any desired solar zenith angle) and white-sky albedos (as is done for MOD43C1). Alternately, the parameters can be used directly with a simple polynomial to easily estimate the black-sky albedo with good accuracy for any desired solar zenith angle.

Mean Cloudsat surface reflectivity (CCCM-4): Values are all default values

Standard Deviation of CloudSat surface reflectivity (CCCM-5)): Values are all default values

Total number of CloudSat profiles (CCCM-6): Number of CloudSat profiles over a CERES footprint

Total number of CloudSat clear-profiles (CCCM-7): Number of cloud-less CloudSat profiles over a CERES footprint

Total number of good CloudSat profiles (CCCM-8): Number of non-default CloudSat profiles over a CERES footprint

Total number of CALIPSO profiles (CCCM-9): Number of CALIPSO profiles over a CERES footprint

Total number of CALIPSO clear profiles (CCCM-10): Number of cloud-less CALIPSO profiles over a CERES footprint

Total number of good CALIPSO profiles (CCCM-11): Number of non-default CALIPSO profiles over a CERES footprint

Cloud group area percent coverage (CCCM-12): PSF weighted percent coverage of each cloud group over the CERES footprint.
The sum of the PSF weight for profiles in a cloud group / total PSF weight of all profiles. The all profile does not include bad profiles. Bad profiles are those when both CALIPSO and CloudSat profiles are bad. The sum of cloud area of all groups should be equal to 100 - Clear (cloud-free) area percent coverage.

Cloud layer top level height (CCCM-13): Starting from the top of the profile, the height of the level where the first layer of cloud occurs is defined as the top height. Whenever CALIPSO identifies a cloud top, the cloud top is kept. In addition, if CloudSat identifies a cloud top at the height where the distance from any CALIPSO identified cloud tops is greater than 480 m, the CloudSat cloud top is kept.

If this level is from a CloudSat profile and there is a corresponding CALIPSO top within 480 m, the CALIPSO top is used instead. The profile is transverse downward. A new cloud top is identified after reaching a cloud layer after a layer(s) when CALIPSO is cloud free regardless of whether there is a break in CloudSat or when there are no CALIPSO clouds in the vicinity, but a cloud layer occurs after a CloudSat cloud-free layer. This is repeated until the surface is reached or CALIPSO is attenuated and no CloudSat clouds remain. If the number of layers exceeds six, the top of the lower layer of two layers with minimum separation is removed. This is repeated until the number of layers equals six.

Cloud top source flag (CCCM-14): The source flag is a two digit number.
The highest order digit is either a 1 - CALIPSO height or 2 - CloudSat height was used.
The second digit is which instruments saw the cloud with 3 - for both.
The allowable flags would then be
11 - CALIPSO only
13 - CALIPSO height, but CloudSat reported clouds between top and base
14 – CALIPSO height, Lowest height of CALIPSO signal because CALIPSO signal was completely attenuated and CloudSat did not report clouds (base only).
22 - CloudSat only
23 - CloudSat height, but CALIPSO reported clouds between top and base
24 - CloudSat height, but CALIPSO was completely attenuated before CloudSat top

Cloud layer base level height (CCCM-15): A base is the height of the top level of the first cloud-free layer below a cloud layers in the profile. Becase all CALIPSO clod bese heights are kept, there may be multiple cloud bases if there are breaks in the CALIPSO profile even if the CloudSat profile does not have them. If the CALIPSO profile is completely attenuated and there is no corresponding CloudSat cloud, then the base is the lowest height where CALIPSO detected the signal. If the number of layers exceeds six, the base of the higher layer of two layers with minimum separation is combined. This is repeated until the number of layers equals six.

Cloud base source flag (CCCM-16): The source flag is a two digit number.
The highest order digit is either a 1 - CALIPSO height or 2 - CloudSat height was used.
The second digit is which instruments saw the cloud with 3 - for both and 4 - for CALIPSO attenuation being added.
The allowable flags would then be
11 - CALIPSO only
13 - CALIPSO height, but CloudSat reported clouds between top and base
14 - CALIPSO height used, but CALIPSO was attenuated at base layer (i.e. CALIPSO base lower than CloudSat or no CloudSat clouds in layer)
22 - CloudSat only
23 - CloudSat height, but CALIPSO reported clouds between top and base
24 - CloudSat height, but CALIPSO was attenuated before CloudSat base

Precipitation flag CloudSat (CCCM-17): The predominant precipitation type if any present from the CloudSat CLDCLASS Precipitation flag. Otherwise, it is set to none. The precipitation flag comes from CloudSat CLDCLASS product. The most frequent occurring flag within a cloud group is kept.

0 = no precipitation
1 = liquid precipitation
2 = solid precipitation
3 = possible drizzle

CALIPSO aerosol layer (overlapping with clouds) top level height (CCCM-18): The top height of the thickest aerosol layer within the cloud group. Aerosol layer height is determined by CALIPSO (from VFM product). One layer per cloud group is kept within a CERES footprint.

CALIPSO aerosol layer (overlapping with clouds) base level height (CCCM-19): The base height of thickest aerosol layer within the cloud group. Aerosol layer height is determined by CALIPSO (from VFM product). One layer per cloud group is kept within a CERES footprint.

Mean CALIPSO signal attenuation level (cloud) (CCCM-20): Mean height that the CALIPSO signal is completely attenuated within each cloud group.

Cloud-free area percent coverage (CALIPSO-CloudSat) (CCCM-21): PSF weighted percent coverage of cloud free area. Cloud mask is based on CALIPSO and CloudSat, i.e. Sum of the PSF weight cloud-free profiles / total PSF weight of good profiles.

Cloud free profiles are those which both CALIPSO and ClodSat profiles do not have clouds. If either CALIPSO or CloudSat profiles is bad, clouds are identified from the other good profile. If both CALIPSO and CloudSat profiles are bad, the profile is excluded from both denominator and numerator. If CALIPSO signal is attenuated by aerosol layers and the collocated CloudSat profile does not contain any clouds, the profile is considered to be a cloud-free profile.

CALIPSO aerosol area percent coverage without clouds (CCCM-22): PSF weighted percent coverage of cloud free with aerosol area. That is the sum of PSF weight of profiles with aerosol, but without clouds divided by the total PSF weight of good profiles. Aerosol layers are identified by CALIPSO.

CALIPSO aerosol layer (over clear-area) top level height (CCCM-23): The top height of aerosol layer over cloud-free area identified by CALIPSO and CloudSat. The aerosol mask from all CALIPSO (from VFM product) cloud-free profiles are combined into one profile. Aerosol layer height is determined by traversing from top to surface or attenuation layer. The height of the top level of the first layer with aerosol is used. This step is repeated after each aerosol free layer. Up to sixteen layers are kept within a CERES footprint. First release is limited to six.

CALIPSO aerosol layer (over clear-area) base level height (CCCM-24): The base height of aerosol layer over cloud-free area identified by CALIPSO and CloudSat. The aerosol mask from all CALIPSO (from VFM product) cloud-free profiles are combined into one profile. The height of the top level of the first aerosol-free layer after aerosol is detected is used. Up to six layers are kept.

Mean CALIPSO signal attenuation level height (aerosol area) (CCCM-25): Mean height of the level of the first layer that the CALIPSO signal is completely attenuated in cloud-free profiles.

CALIPSO signal attenuation area percent coverage (CCCM-26): Percent coverage of area over a CERES footprint that CALIPSO signal is completely attenuated. Sum of the PSF weight of profiles with attenuation / total PSF weight of good profiles.

Clear area percent coverage MODIS (CCCM-27): Percent average of MODIS-derived clear area over the cloud-free portion identified by CALIPSO and CloudSat.

Cloud percent coverage over group from MODIS (CCCM-28): PSF-weighted MODIS-derived cloud percent coverage over each cloud group.

Mean group visible optical depth from MODIS radiance (CCCM-29): Mean PSF-weighted MODIS-derived cloud optical depth averaged over each cloud group. Cloud optical depth is derived by the CERES Edition3 and enhanced cloud algorithms. The enhanced algorithm is a simple improved MODIS cloud retrieval algorithm. The improvement is done using CALIPSO and CloudSat cloud mask. If the MODIS derived cloud top height is different form the topmost cloud top height derived from CALIPSO and CloudSat, the algorithm change the cloud top. If the optical thickness is less than 2, the MODIS cloud top is put the halfway between the merged cloud top and base. If the optical thickness is greater than 2, the top is put at the optical thickness of 1 from the top. After changing the cloud top height, we apply the same Edition3 cloud algorithm.

Mean group logarithm of visible optical depth from MODIS radiance (CCCM-30): Mean PSF-weighted natural logarithm of MODIS-derived cloud optical depth averaged over each cloud group. Cloud optical depth is derived by the CERES Edition3 and enhanced cloud algorithms.

Mean group cloud top height from MODIS radiance (CCCM-31): Mean PSF-weighted MODIS derived cloud top height by the CERES Edition3 and enhanced cloud algorithms over each cloud group. MODIS cloud top heights are above ground level.

Mean group water particle radius from MODIS radiance (3.7) (CCCM-32): Mean PSF-weighted water cloud particle effective radius derived from 3.7 micron channel over each cloud group. Cloud phase is identified by MODIS.

Mean group ice particle radius from MODIS radiance (3.7) (CCCM-33): Mean PSF-weighted ice cloud particle diameter derived from 3.7 micron channel over each cloud group. Cloud phase is identified by MODIS.

Mean group cloud particle phase from MODIS radiance (3.7) (CCCM-34): Mean PSF-weighted particle phase derived from 3.7 micron channel over each cloud group. One is water and two is ice.

Mean group water particle radius from MODIS radiance (2.1) (CCCM-35): Mean PSF-weighted water cloud particle effective radius derived from 2.1 micron channel over cloud group. Cloud phase is identified by MODIS using 3.7 micron channel.

Mean group ice particle radius for cloud group (2.1) (CCCM-36): Mean PSF-weighted ice cloud particle diameter derived from 2.1 micron channel over each cloud group. Cloud phase is identified by MODIS using 3.7 micron channel.

Aerosol layer mean:
Up to 16 layers within a CERES footprint are kept. All aerosol layers included in the CALIPSO 5 km aerosol layer mean product are included without mixing and averaging multiple layers if there is less than 16 layers within the CERES footprint. If the number of layers exceeds 16, then some layers are merged. The merging process is done by horizontal average starting at 5 km and going to 20 km and 80 km to find at least five layers at that horizontal average. The two aerosol layers that have the minimum absolute difference in top and base heights are combined. This procedure is repeated until sixteen layers are reached. In the cases where layers are combined, the values for the combined layers are PSF weighted and the mean reported.

CALIPSO aerosol layer percent coverage (CCCM-37): Percent coverage of area over a CERES footprint that the specific CALIPSO aerosol layer covers. Sum of the PSF weight of MODIS pixels with this layer assigned / total PSF weight of MODIS pixels in track.
CALIPSO aerosol layer top level height (CCCM-38): Aerosol layer top height extracted from the CALIPSO 5 km aerosol layer mean product.

CALIPSO aerosol layer base level height (CCCM-39): Aerosol layer base height extracted from the CALIPSO 5 km aerosol layer mean product.

CALIPSO aerosol layer opacity flag (CCCM-40): Opacity flag extracted from the CALIPSO 5 km aerosol layer mean product.

CALIPSO layer aerosol horizontal averaging distance (CCCM-41): Horizontal averaging extracted from the CALIPSO 5 km aerosol layer mean product.

CALIPSO aerosol feature classification flags (CCCM-42): Feature classification flags extracted from the CALIPSO 5 km aerosol layer mean product.

Mean CALIPSO aerosol feature optical depth at 532 nm (CCCM-43): CALIPSO derived aerosol optical depths and over a CERES footprint extracted from the CALIPSO 5 km aerosol layer mean product. The aerosol layer top and base heights are in CCCM-38 and CCCM-39.

Mean CALIPSO feature optical depth uncertainty at 532 nm (CCCM-44): CALIPSO derived aerosol optical depth uncertainty over a CERES footprint extracted from the CALIPSO 5 km aerosol layer mean product. The aerosol layer top and base heights are in CCCM-38 and CCCM-39.

Mean CALIPSO feature optical depth at 1064 nm (CCCM-45): CALIPSO derived aerosol optical depths over a CERES footprint extracted from the CALIPSO 5 km aerosol layer mean product. The aerosol layer top and base heights are in CCCM-38 and CCCM-39.

Mean CALIPSO feature optical depth uncertainty at 1064 nm (CCCM-46): CALIPSO derived aerosol optical depth uncertainty over a CERES footprint extracted from the CALIPSO 5 km aerosol layer mean product. The aerosol layer top and base heights are in CCCM-38 and CCCM-39.

Mean CALIPSO relative humidity in aerosol layer (CCCM-47): Relative humidity of the aerosol layer extracted from the CALIPSO 5 km aerosol layer mean product. The aerosol layer top and base heights are in CCCM-38 and CCCM-39.

Mean CALIPSO aerosol layer CAD score (CCCM-48): CAD score of the aerosol layer extracted from the CALIPSO 5 km aerosol layer mean product.

Mean CALIPSO aerosol optical thickness over cloud free area (CCCM-49): PSF weighted mean aerosol optical thickness. For each MODIS pixel, the column aerosol optical thickness is calculated from the layer optical depth from the CALIPSO 5 km aerosol layer mean product. There might be some disagreements of cloud mask between this variable and CCCM-13 and CCCM-15.

Standard deviation CALIPSO aerosol optical thickness over cloud free area (CCCM-50): The PSF-weighted standard deviation of aerosol optical thickness. For each MODIS pixel, the column aerosol optical thickness is calculated from the layer optical depth from the CALIPSO 5 km aerosol layer mean product. There might be some disagreements of cloud mask between this variable and CCCM-13 and CCCM-15.

Cloud layer mean

CALIPSO layer cloud type profile (CCCM-51): The predominant cloud type from CALIPSO extracted from the CALIPSO VFM feature flag is assigned to each layer.

Cloud fraction profile (CCCM-52): Volumetric cloud fraction vertical profile derived from CALIPSO and CloudSat data. It is the percentage of CALIPSO bins within the model layer in all valid profiles with clouds to the total number of bins within the model layer in all valid profiles. CloudSat clouds are assigned to CALIPSO bins.

Mean CALIPSO cloud layer CAD score (CCCM-53): PSF weighted CAD score extracted from CALIPSO 5 km cloud layer mean product.

Mean CALIPSO cloud layer extinction coefficient at 532 nm (CCCM-54): PSF weighted mean CALIPSO derived extinction coefficient profile from the CALIPSO 5 km cloud profile product. Extinctions with QC flag = 1, 0, 2, and 16, CAD score -100 to 100, 101, and 102 are included in the average.

Mean CALIPSO constrained cloud layer extinction coefficient at 532 nm (CCCM-55): PSF weighted mean CALIPSO derived extinction coefficient profile from the CALIPSO 5 km cloud profile product. Extinctions with QC flag = 1, CAD score -100 to 100, 101, and 102 are included in the average.

Mean logarithm of CALIPSO extinction coefficient at 532 nm (CCCM-56): PSF weighted mean logarithm of CALIPSO derived extinction coefficient profile from the CALIPSO 5 km cloud profile product. Extinctions with QC flag = 1, 0, 2, and 16, CAD score -100 to 100, 101, and 102 are included in the average.

CALIPSO extinction coefficient uncertainty at 532 nm (CCCM-57): PSF weighted mean extinction coefficient profile from the CALIPSO 5 km cloud profile product.

Mean CALIPSO ice water content (CCCM-58): Not available yet

Standard Deviation of CALIPSO ice water content (CCCM-59): Not available yet.

CALIPSO ice water content uncertainty (CCCM-60): Not available yet.

Mean CloudSat radar only liquid effective radius (CCCM-61): PSF weighted mean effective radius of warm clouds derived from radar only algorithm from CloudSat 2B-CWC.

Standard deviation of CloudSat radar only liquid effective radius (CCCM-62): Standard deviation of effective radius of warm clouds derived from radar only algorithm from CloudSat 2B-CWC.

Mean CloudSat radar only liquid effective radius uncertainty (CCCM-63): PSF weighted mean effective radius uncertainty derived from radar only algorithm from CloudSat 2B-CWC. Currently, this variables contains only a default value.

Mean CloudSat radar only ice effective radius (CCCM-64): PSF weighted mean effective radius of ice crystals derived from radar only algorithm from CloudSat 2B-CWC.

Standard deviation CloudSat radar only ice effective radius (CCCM-65): Standard deviation of effective radius of ice crystals derived from radar only algorithm from CloudSat 2B-CWC.

Mean CloudSat radar only ice effective radius uncertainty (CCCM-66): PSF weighted mean effective radius uncertainty derived from radar only algorithm from CloudSat 2B-CWC. Currently, this variables contains only a default value.

Mean CloudSat radar only liquid water content (CCCM-67): PSF weighted mean liquid water content radius of warm clouds derived from radar only algorithm from CloudSat 2B-CWC.

Standard deviation CloudSat radar only liquid water content (CCCM-68): Standard deviation of water content of warm clouds derived from radar only algorithm from CloudSat 2B-CWC.

Mean CloudSat radar only liquid water content uncertainty (CCCM-69): PSF weighted mean effective radius uncertainty derived from radar only algorithm from CloudSat 2B-CWC.

Mean CloudSat radar only ice water content (CCCM-70): PSF weighted mean ice water content derived from radar only algorithm from CloudSat 2B-CWC.

Standard deviation CloudSat radar only ice water content (CCCM-71): Standard deviation of effective radius of ice crystals derived from radar only algorithm from CloudSat 2B-CWC.

Mean CloudSat radar only ice effective water content (CCCM-72): PSF weighted mean effective radius uncertainty derived from radar only algorithm from CloudSat 2B-CWC.

CloudSat cloud type histogram (CCCM-73): Cloud type histogram derived from CloudSat 2B-CLDCLASS mask. It is 100 times percent of layers with given cloud type divided by total number of cloud layers.

Vertical Irradiance Profile
Clouds
Cloud Data Sources for Irradiance Computations
Irradiance vertical profiles are computed for each cloud profile group described in the Cloud and aerosol mask section. FLCKKR radiative transfer model (with a 2 stream approximation) is used. Cloud optical properties used in the computations are

1) CALIPSO derived extinction (532 nm) profile if it is available
2) Convert CloudSat derived IWC and LWC to the extinction if they are available but CALIPSO extinction is not available.
3) MODIS derived optical thickness if 1) and 2) are not available.

In the case of 1) and 2), column scaled optical thickness integrated from vertical extinction profile is normalized by the MODIS derived scaled optical thickness, $\tau_{MODIS}(1-g_{MODIS}) = \alpha \sum \beta \Delta z(1-g)$, where α is a free parameter to scale CALIPSO and CloudSat derived scaled optical thickness by MODIS derived scaled cloud optical thickness by the Ed3 CERES cloud algorithm.

Aerosols
Aerosol Data Sources for Irradiance Computations
Calipso
Eight 8 aerosol layers per FOV with a top and a bottom height in (km)
532 and 1064 nm optical depths for each of the eight layers
The horizontal averaging length in km associated with each of the eight layer.
Feature class flag that may be of use in aerosol typing (TBD)
Data occurrence looks to be sparse.
MODIS
Total column AOT at multiple wavelengths.
-Ocean :(0.47, 0.55, 0.66, 0.87, 1.2, 1.6, and 2.1 microns)
-Land :(0.47,0.55,0.66)
Only if Clear Sky in FOV
Needs to access SSFA file NOT currently read by RT code
Match
Daily data on a Coarse grid is mach larger than MODIS FOV size
Aerosol optical depth and profiles for seven types.
[DustSmall(0.1um) DustLarge(2.5um) SO4 SeaSalt Soot Soluble Insoluble]
These seven types are tied to spectral (extinction, asymmetry parameter and single scatter

albedo) within the CERES radiative transfer code (FLux model for CERES with K-distribution and correlated-K for Radiation: FLCKKR).

RT Model use of Aerosol

The RT model will accept multiple wavelength AOT to override the spectral extinction shapes that are implicit of an aerosol type over the wavelength range given. Outside of the multi-wavelength AOT range the spectral extinction is tied to the 500 nm extinction according to the spectral extinction shape of the aerosol type.

In practice a log(aot) vs log(wavelength) fit is done over the input wavelengths to avoid extreme slopes in the spectral extinction shape used.

The RT model accepts a profile for each aerosol type used that is the percent of aerosol AOT@500nm within a computational layer.

The Hierarchy of using aerosol properties is following. If CALIOP derived 532 and 1064 nm aerosol optical thickness are available from the layer mean product, we use those optical thickness. If CAIOP derived aerosol optical thickness is not available, we use MODIS derived aerosol optical thickness. Wavelengths used for the aerosol optical thickness retrieval are 0.47, 0.55, 0.66, 0.87, 1.2, 1.6, and 2.1 μm over ocean and 0.47, 0.55, and 0.66 μm over land. If both CALIOP and MODIS does provide aerosol optical thickness, we use 0.66 μm aerosol optical thickness from MATCH.

Aerosol types used for irradiance computations are; DustSmall(0.1um), DustLarge(2.5um), SO4, SeaSalt, Soot, Soluble, Insoluble. The aerosol type determines the spectral shape of the optical property of aerosols. Optical properties from Lacis are used to compute single scattering albedo and asymmetry parameter, based on MATCH derived aerosol type. Outside of the multi-wavelength AOT range the spectral extinction is tied to the 500 nm extinction according to the spectral extinction shape of the aerosol type. The relation of a log of the aerosol optical thickness versus log of the corresponding wavelength is computed over the input wavelengths to detect extreme slopes in the spectral extinction shape.

Modeled aerosol type (CCCM-74): Aerosol type used for flux computations; 1 = DustSmall(0.1um) , 2 = DustLarge(2.5um), 3=SO4, 4=SeaSalt, 5=Soot, 6=Soluble, 7=Insoluble.

CALIPSO derived optical thickness (if it is available) or MODIS derived aerosol optical thickness (if CALIPSO optical thickness is not available) are used. If neither optical thickness are available, the aerosol optical thickness from MATCH is used. Aerosol type is either from CALIPSO (if it is available) or from MATCH. Optical properties from Lacis are used to compute single scattering albedo and asymmetry parameter.

Aerosol source flag (CCCM-75): Source of modeled aerosol source.

0 MATCH
1 SSFA MODIS Ocean 7 wavelength Normalize to CALIPSO
2 SSFA MODIS Ocean 7 wavelength
3 SSFA MODIS Land 3 wavelength normalized to CALIPSO
4 SSFA MODIS Land 3 wavelength

Surface albedo source (CCCM-75): Source of the surface albedo used for computations, either MODIS spectral albedo, Jin's ocean, or Jin's snow.

Pressure profile (CCCM-76): Atmospheric pressure at computational levels from GEOS-4

Temperature profile (CCCM-77): Atmospheric temperature at computational levels from GEOS-4

Water vapor mixing ratio profile (CCCM-78): Water vapor mixing ratio at computational levels from GEOS-4

Ozone mixing ratio profile (CCCM-79): Ozone mixing ratio at computational levels from MOA

Surface geopotential height (CCCM-80):

Lifting condensation level (CCCM-81): Lifting condensation level computed from thermodynamic variables from GEOS-4

Aerosol extinction coefficient profile used (CCCM-82): Aerosol extinction coefficient (at 500 nm) vertical profile used for flux computations.

Aerosol single scattering albedo profile used (CCCM-83): Aerosol single scattering albedo (at 500 nm) vertical profile used for flux computations.

Cloud extinction coefficient profile used (CCCM-84): Cloud extinction coefficient (at ? nm) used for flux computations.

Liquid water content profile used (CCCM-85): Liquid water content vertical profile used for flux computations.

Ice water content profile used (CCCM-86): Ice water content vertical profile used for flux computations.

SW downward flux profile untuned (CCCM-87): Untuned downward irradiance profile at 132 levels (+ up to 4 levels below MSL if the altitude of the surface is below MSL) computed with CALIPSO and CloudSat derived cloud masks.
Clouds
MODIS derived optical thickness from the CERES cloud Ed 3 algorithm averaged along the ground track of MODIS is vertically distributed using CALIPSO derived extinction, and CloudSat-derived liquid water and ice water contents. To avoid the effect of different cloud particle phases, optical thicknesses are converted to scale optical thickness, the

vertical distribution is obtained, and scaled optical thickness vertical distribution is converted back to optical thickness vertical distribution.

Fluxes are computed for each cloud group and cloud-less columns separately and are averaged weighted by respective area coverage.
All fluxes have 4-components that are computed with 1) clouds and aerosols, 2) clouds only 3) clear-sky with aerosols, and 4) clear-sky with no aerosol.

SW upward flux profile untuned (CCCM-88): MODIS spectral albedo over land, Jin's ocean and snow spectral albeds are used.

LW downward flux profile untuned (CCCM-89):
LW upward flux profile untuned (CCCM-90): Irradiance profiles are computed in the way that shortwave irradiances (CCCM-87, 88) are computed.

WN downward flux profile untuned (CCCM-91):
WN upward flux profile untuned (CCCM-92): Irradiance profiles are computed in the way that shortwave irradiances (CCCM-87, 88) are computed.

SW downward flux TOA untuned (MODIS enhanced) (CCCM-93)
SW upward flux TOA untuned (MODIS enhanced) (CCCM-94)
SW downward flux surface untuned (MODIS enhanced) (CCCM-95)
SW upward flux surface untuned (MODIS enhanced) (CCCM-96)
Shortwave up- and downward irradiances at TOA and surface computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm applied to the along track MODIS pixels (CCCM-95, 96, 97). It contains default value if the retrieved values from MODIS enhanced cloud algorithm applied to pixels over the along track of CALIPSO and CloudSat are not available.
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LW downward flux surface untuned (MODIS enhanced) (CCCM-97)
LW upward flux TOA untuned (MODIS enhanced) (CCCM-98)
LW upward flux surface untuned (MODIS enhanced) (CCCM-99)
Longwave irradiances at TOA and surface computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm applied to the along track MODIS pixels. It contains default value if the retrieved values from MODIS enhanced cloud algorithm applied to pixels over the along track of CALIPSO and CloudSat are not available.
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WN downward flux surface untuned (MODIS enhanced) (CCCM-100)
WN upward flux TOA untuned (MODIS enhanced) (CCCM-101)
WN upward flux surface untuned (MODIS enhanced) (CCCM-102)
Window irradiances irradiances at TOA and surface computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm applied to the along track MODIS pixels. It contains default value if the retrieved values from MODIS enhanced

cloud algorithm applied to pixels over the along track of CALIPSO and CloudSat are not available.

SW all-sky upward TOA spectral flux untuned (CCCM-103)
SW all-sky downward TOA spectral flux untuned (CCCM-104)
SW all-sky upward surface spectral flux untuned (CCCM-105)
SW all-sky downward surface spectral flux untuned (CCCM-106)
Shortwave all-sky up- and downward spectral irradiances at TOA and surface computed with CALIPSO, CloudSat and MODIS derived cloud and aerosol properties. Wavelength information is given by CCCM-126. The sum of irradiances over wavelength should equal to the TOA or surface all-sky irradiances from CCCM-87 and CCCM-88.

LW all-sky upward TOA spectral flux untuned (CCCM-107)
LW all-sky upward surface spectral flux untuned (CCCM-108)
LW all-sky downward surface spectral flux untuned (CCCM-109)
Longwave all-sky up- and downward spectral irradiances at TOA and surface computed with CALIPSO, CloudSat and MODIS derived cloud and aerosol properties. Wavelength information is given by CCCM-127. The sum of irradiances over wavelength should equal to the TOA or surface all-sky irradiances from CCCM-89 and CCCM-90.

LW TOA modeled unfiltered radiance untuned (CCCM-110): TOA longwave upward unfiltered radiance computed with CALIPSO, CloudSat and MODIS along a-train ground track derived properties. The modeled radiance should be compared with CERES LW unfiltered radiance.

WN TOA modeled unfiltered radiance untuned (CCCM-111): TOA longwave upward unfiltered radiance computed with CALIPSO, CloudSat and MODIS along a-train ground track derived properties. The modeled radiance should be compared with CERES WN unfiltered radiance.

WN TOA modeled filtered radiance untuned (CCCM-112): TOA longwave upward filtered radiance computed with CALIPSO, CloudSat and MODIS along a-train ground track derived properties. The modeled radiance should be compared with CERES WN filtered radiance.

WN TOA upward flux untuned (CCCM-113): TOA window flux of which spectral range matches with the CERES window channel. The flux is computed with CALIPSO and CloudSat, MODIS cloud and aerosol properties.

LW TOA modeled unfiltered radiance enhanced (CCCM-114): TOA longwave upward unfiltered radiance computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm. The modeled radiance should be compared with CERES LW unfiltered radiance.

WN TOA modeled unfiltered radiance enhanced (CCCM-115): TOA longwave upward unfiltered radiance computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm. The modeled radiance should be compared with CERES WN unfiltered radiance.

WN TOA modeled filtered radiance enhanced (CCCM-116): TOA longwave upward filtered radiance computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm.. The modeled radiance should be compared with CERES WN filtered radiance.

WN TOA upward flux enhanced (CCCM-117): TOA window flux of which spectral range matches with the CERES window channel. The flux is computed with MODIS cloud properties derived by the enhanced CERES cloud algorithm.

Irradiance modeling source flag (CCCM-118):
Four DIGITS [Thousands: Hundreds: Tens : Ones]
[CLOUD: AOTTYPE: PROFILE: AOT]

CLOUD Data Source (Thousands Digit)
0000: No clouds
1000: MODIS ONLY
2000: MODIS & CALIPSO
3000: MODIS & CloudSat
4000: MODIS & CALIPSO & CloudSat
5000: Ed2 SSF only based clouds

Aerosol TYPE Source (Hundreds Digit)
000 : MATCH constituent TYPES : DustSm,DustLg,SO4,SSLT,Soot,Solub,Insol
100 : CALIPSO feature_class_flag
clean marine ,dust ,polluted continental ,clean continental, polluted dust,6 smoke ,other

Aerosol PROFILE Source (Tens digit)
00 : MATCH PROFILE : No CALIPSO Layer bounds , NO CALIPSO Extinction
10 : CALIPSO Layer Bounds Exist, NO CALIPSO Extinction
20 : Both CALIPSO Layer bounds and Extinctions are present.

Aerosol OPTICAL DEPTH Source(Ones Digit)
0 : MATCH Profiles and AOTs
1 : SSFA MODIS ocean 7 wavelengths normalized to CALIPSO
2 : SSFA MODIS ocean 7 wavelengths
1 : SSFA MODIS land 3 wavelengths normalized to CALIPSO
2 : SSFA MODIS land 3 wavelengths

Flux confidence flag (CCCM-119)
TBD

Layer center height

Irradiance surface level (CCCM-120) : Index of the surface height (CCCM-124) used for irradiance computation.

Layer center height (clouds and aerosols) (CCCM-121): The layer center height of the height coordinate for layer mean cloud properties derived from CloudSat (CCCM-51, -52, and -61 through -72).

Level height (clouds and aerosols) (CCCM-122): The edge height of layers used for CCCM-121.

Layer center height (irradiances) (CCCM-123): The layer center height for the height coordinate for irradiance profiles, from CCCM-82 through CCCM-86.

Level height (irradiances) (CCCM-124): The edge height of layers the irradiance profiles are computed, CCCM-76 through CCCM-79, and CCCM-87 through CCCM-92.

CALIPSO layer center height (layer mean) (CCCM-125): The layer center height for CALIPSO layer product, from CCCM-53 through CCCM-60.

CALIPSO level height (layer mean) (CCCM-126): The edge height of layers used for CCCM-125.

Shortwave computational spectral bands (CCCM-127): The edge of shortwave spectral band used for irradiance computations.

Longwavewave computational spectral bands (CCCM-128): The edge of longwave spectral band used for irradiance computations.